# A CIRCUIT APPROACH TO THE ANALYSIS OF ELECTRICAL MACHINERY

By

HERMAN EDWARD KOENIG

B.S., University of Illinois, 1947
M.S., University of Illinois, 1949

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ELECTRICAL ENGINEERING
IN THE GRADUATE COLLEGE OF THE
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When a circuit approach is used, the analysis of electrical machinery can be conveniently divided into three major parts; (a) establish a set of differential equations describing the behavior of the machine in terms of lumped circuit parameters, (b) evaluate the lumped circuit parameters in terms of the physical dimensions of the machine, (c) obtain the solution to the resultant set of equations to give the general transient response or frequency response. The first two parts in the solution of the problem are considered in this thesis.

The problem of writing the differential equations for the machine appears as a basic circuit problem and as such, is subject to all the techniques of circuit analysis. It was found unnecessary to introduce the complexity of tensor analysis as advocated by previous authors. Simple matrix algebra is found to be sufficient to analyze the present machinery problems and is used freely to reduce the complex problem to one that can be readily comprehended. The two-reaction theory of Blondel, as applied to the three-phase machine, appears as a simple matrix transformation which reduces the set of variable coefficient differential equations to a set of constant coefficient differential equations. A more general transformation to accomplish this same result is derived for an "n" phase induction machine.

The commutating-machine problem is considered as a switching problem and a set of differential equations derived which describe the commutating phenomenon as well as the external characteristics of the machine under transient conditions.

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The problem of evaluating the circuit parameters is considered in detail with special emphasis on the direct-current machine. To reduce the complexity of the problem of evaluating the field distribution in the machine, the overall field problem is divided into four relatively independent regions and the components of inductance determined for each coil or element of the machine The inductance of each circuit in the machine is then obtained by forming the sum of the self and mutual inductances between each pair of elements in the circuit as dictated by the equations derived in the first part of the analysis.

Regions of the machine having boundary contours too complex to yield to analytical analysis are solved graphically and a set of curves given which show the field distribution as a function of machine dimensions.

The effects of eddy currents in the solid iron frame are simulated by an equivalent inductance and resistance derived from the dynamic field of equations of the frame region.

It is now possible to numerically evaluate the coefficients of the differential equations and to study their solution with the aid of a digital or analogue type computer. Since the circuit parameters are directly related to the physical dimensions of the machine, it is conceivable that an analogue or digital computer can ultimately be used to design rotating machinery.

Although the saturation effects of the iron have been neglected in this thesis, the rapid iterative ability of the digital computer offers hope of ultimately including these effects in the analysis.

# VITA

Herman Edward Koenig was born December 12, 1924, in Marissa, Illinois. He graduated from Marissa Township High School in 1942. After completing two semesters at Washington University in 1944, he entered the University of Illinois and received the degree of Bachelor of Science, with high honors, from that institution in August, 1947. For the following year, he was employed by Delco Products Division of General Motors. In 1948, he entered the Graduate College of the University of Illionis and received his Master of Science degree in August, 1949. He then served as an instructor while continuing his graduate work.